CHEM-NUCLEAR SYSTEMS, LLC
Subsidiary of Duratek
740 Osborn Road • Barnwell, South Carolina 29812

July 2, 2003
BC –063003-66
LAB-07-03-02

Mr. Henry Porter, Assistant Director
Division of Waste Management
Bureau of Land & Waste Management
SC Dept of Health & Environmental Control
2600 Bull Street
Columbia, SC 29201

Dear Mr. Porter:

Enclosed please find a copy of Environmental Radiological Performance Verification of the Barnwell Waste Disposal Facility Summary, BEDL-03-003, which summarizes how Chem-Nuclear obtained the projected hypothetical maximum dose rate for the Barnwell site. This is the non-proprietary report which summarizes the primary ERPV Reports. The reports show that the maximum projected hypothetical dose rate is 13 mrem TEDE annually. The actual dose rate is negligible because there are no known consumers of surface water immediately downgradient of the CNS property.

Should you have any questions, feel free to contact us.

Sincerely,

CHEM-NUCLEAR SYSTEMS, LLC

William B. House
Vice President, Regulatory Affairs

Attachment

Printed on recycled paper

BEDL-03-003

ENVIRONMENTAL RADIOLOGICAL PERFORMANCE VERIFICATION OF THE BARNWELL WASTE DISPOSAL FACILITY

SUMMARY

JULY 2003

PREPARED BY: _____

REVIEWED BY: _____

APPROVED BY: _____

CHEM-NUCLEAR SYSTEMS
ENVIRONMENTAL AND DOSIMETRY LABORATORY
BARNWELL, SOUTH CAROLINA

TABLE OF CONTENTS

Page No.

1.0 INTRODUCTION

This report summarizes the Environmental Radiological Performance Verification (ERPV) of the Barnwell Waste Disposal Facility (Barnwell Site). The summary is provided to support the Chem-Nuclear Systems' (CNS) renewal application for South Carolina Radioactive Materials License 097, which governs the operations of the Barnwell Waste Management Facility (Barnwell Site). The ERPV uses environmental measurements and models to show the Barnwell Site meets or exceeds radiological performance objectives. The ERPV was conducted with South Carolina Department of Health and Environmental Control (SCDHEC) input and concurrence.

This report contains four sections as follows. Section 2.0 provides background information about regulations, environmental history, and environmental conditions encountered at Barnwell and other low-level radioactive waste disposal sites. Section 3.0 addresses radionuclides in the groundwater pathway. Measurements made in the groundwater pathway are used to project a maximum hypothetical dose rate at the compliance point on CNS property boundary. Section 4.0 contains the evaluation of potential radionuclides in the air pathway and section 5.0 summarizes ERPV results.

2.0 BACKGROUND

This section provides background information about the regulatory requirements for measuring site performance, the environmental history of the Barnwell Site, and the environmental conditions encountered at other low-level radioactive waste disposal sites.

2.1 Regulatory Requirements

Chem-Nuclear Systems is licensed by SCDHEC to operate a disposal facility for the disposal of low-level radioactive waste. Condition 98, Objective E of License No. 097 requires CNS to demonstrate by measurement and/or model, during operations and after site closure, that concentrations of radioactive material which may be released to the general environment in groundwater, surface water, air, soil, plants, or animals will not result in an annual dose exceeding an equivalent of 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ of any member of the public. Based on this requirement and SCDHEC request and approval, CNS has conducted the ERPV.

Chem-Nuclear Systems evaluates the groundwater, surface water and air pathways, the primary means by which radioactivity could reach any member of the public after the disposal site closes. The water pathway assumes no engineered cover, and movement of radioactivity occurs under natural (average) groundwater and surface conditions. These conditions were based on numerous water elevation measurements taken over 12 years from over 200 monitoring wells, which are part of the Barnwell Site monitoring program. Similarly, radiological conditions and measurements were based on measurements made from 1982 to 2000 from over 200 monitoring locations. Air pathway analysis assumes emission of gases containing radioactivity due to decomposition of waste, and these gases are uniformly emitted to the land surface. Gas measurements were made during the fall of 1998 and 1999 to measure radionuclides in air in the breathing zone when soil gas concentration is expected to be maximum.

2.2 Environmental Status History - Barnwell Site

Tritium was first measured in the disposal trench sumps in 1974 and in on-site monitoring wells in 1978. In 1990, CNS measured above background tritium where the Barnwell site's groundwater becomes surface water in Mary's Branch Creek on CNS property.

At the current time, actual dose rates from tritium to any member of the public are negligible because there is no known consumer of surface water immediately downgradient of the CNS property. The Savannah River Site and Chem-Nuclear Systems control most of the access to surface and groundwater downgradient of the Barnwell Site.

Table 2.2-1 provides a summary of radionuclides or radioactivity that has been measured in the trench sumps. This table provides information about the radionuclides that are outside waste packages and has the potential to migrate by the groundwater pathway.

TABLE 2.2-1
Trench Standpipe Radionuclide Summary
(12/01/82 – 04/30/97)

^{235}U	^{54}Mn
^{238}U	^{65}Zn
^{60}Co	Gross Alpha*
^{134}Cs	Gross Beta*
^{137}Cs	^{3}H

* Not radionuclide specific, but are indicators of radioactivity outside waste packages.

Table 2.2-2 is a list of 20 radionuclides considered important by SCDHEC. These radionuclides represent most of the radioactivity received at the disposal site. These radionuclides may be representative of most of the

radioactivity in the disposed inventory that could contribute to a potential source term of radioactivity.

TABLE 2.2-2
Top 20 Radionuclides Disposed at the Barnwell Site

^{60}Co	^{134}Cs	^{95}Zr
^{55}Fe	^{65}Zn	^{59}Fe
^{137}Cs	^{51}Cr	^{89}Sr
^{3}H	^{238}U	^{125}I
^{63}Ni	^{85}Kr	^{141}Ce
^{54}Mn	^{58}Co	^{103}Ru
^{90}Sr	^{144}Ce	

With the exception of tritium, Table 2.2-2 radionuclides attributed to the disposal site have not been detected in the Barnwell site's monitoring wells or surface water sampling locations.

2.3 Environmental Status - Other Sites

Environmental monitoring measurements made at existing commercial low-level radioactive waste disposal facilities are indicators of which radionuclides might be important contributors to dose. In this section, CNS summarizes environmental monitoring at other commercial low-level radioactive waste disposal sites obtained from the E-5 Committee on Radioactive Waste Management of the Conference of Radiation Control Program Directors (CRCPD) report. These sites include Sheffield, Illinois; Maxey Flats, Kentucky; Beatty, Nevada; West Valley, New York; and Richland, Washington.

Environmental monitoring data collected between the 1960's and 1990's indicate most low-level radioactive waste disposal sites have reported

tritium migrating from disposed wastes into the environment by groundwater.

Selected radionuclides identified or suspected from environmental monitoring programs at the commercial sites in the E-5 environmental report are included in Table 2.3-1. The E-5 report also identifies above background gross-alpha and beta results and unspecified gamma radioactivity at other commercial sites. According to the E-5 report, most of the radionuclides listed below have either been detected or suspected at sufficiently low concentrations or in locations that are sufficiently isolated that potential and actual exposures from these radionuclides are below regulatory limits.

TABLE 2.3-1
Selected Radionuclides Based on E-5 Report *

^{60}Co	^{155}Eu
^{89}Sr	^{7}Be
^{90}Sr	^{59}Fe
^{134}Cs	^{95}Zr
^{137}Cs	^{103}Ru
^{238}Pu	^{144}Ce
^{239}Pu	^{232}Th
^{14}C	^{3}H
^{54}Mn	

* Report published by the National Low-Level Waste Management Program entitled "Environmental Monitoring Report for Commercial Low-Level Radioactive Waste Disposal Sites (1960's through 1990's)" DOE/LLW-241

3.0 GROUNDWATER

Chem-Nuclear used direct measurements from the Barnwell Site environmental monitoring program to estimate potential (or hypothetical) dose rates to a receptor of surface water derived from groundwater under natural conditions at the CNS property boundary. Natural conditions are defined as conditions that

conservatively mimic the environment long after the disposal site is closed. Chem-Nuclear also calculates dose as hypothetical or potential dose to a non-existent user of water at the boundary of CNS property downgradient of the disposal site.

The conceptual model, which describes the transport of radionuclides, is illustrated in Figure 3-1. Mobile radionuclides travel vertically from the disposal trenches to the water table. Transport occurs at a very slow rate nearly vertically from the water table through Zone 1. Upon entering Zone 2, radionuclides are transported primarily horizontally to Mary's Branch Creek. Horizontal pathlines have been calculated from the disposal area to the creek. These pathline calculations are used to estimate radionuclide concentrations where groundwater discharges into the creek and eventually leaves CNS property. This location is called the compliance point. The dose rates are calculated for a continuous consumer (2 liters per day) of water at the compliance point.

Conceptual Model of Radionuclides in Transport

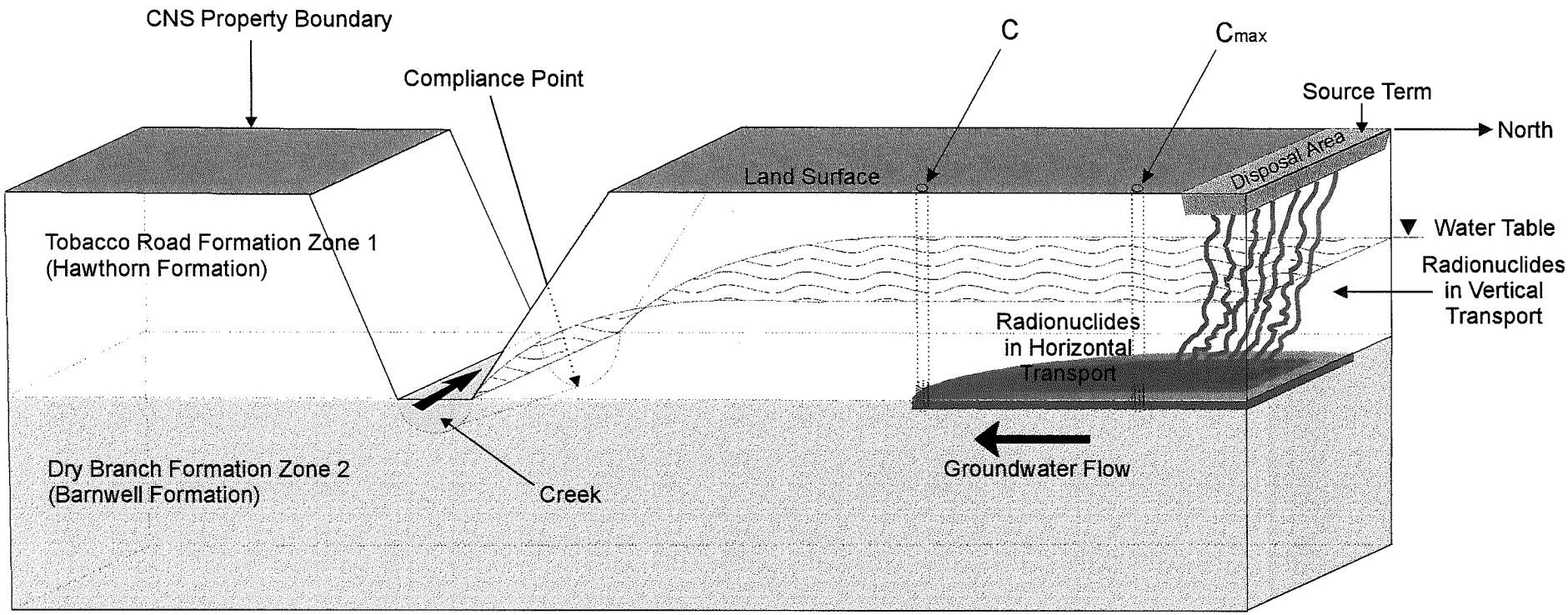

Figure 3-1: Conceptual model describing the transport of radionuclides.

3.1 Selection of Radionuclides for Groundwater Assessment

Hypothetical dose assessment requires the knowledge of which radionuclides can reach the compliance point at the property boundary in 2000 years by the groundwater pathway (see Section 3.2). The radionuclides screened for this criterion are selected as follows:

- Radionuclides which have been detected in the CNS trench monitoring program (Table 2.2-1);
- Top 20 radionuclides (Table 2.2-2);
- Radionuclides ^{99}Tc, ^{129}I, and ^{14}C, which have been requested by SCDHEC;
- Radionuclide ^{94}Nb, which is listed in License 097 waste classification table;
- Radionuclide ^{237}Np, which may be mobile in groundwater;
- Radionuclides which may be present in groundwater at other commercial low-level radioactive waste disposal sites according to the E-5 environmental report (Table 2.3-1);
- Radionuclide ^{36}Cl based on preliminary information provided by the NRC.

The combined list of all the radionuclides screened during this study is provided in Table 3.1-1.

TABLE 3.1-1
Combined Radionuclide List

^{3}H	^{155}Eu	^{239}Pu
^{7}Be	^{55}Fe	^{103}Ru
^{14}C	^{59}Fe	^{89}Sr
^{60}Co	^{125}I	^{90}Sr
^{141}Ce	^{129}I	^{99}Tc
^{144}Ce	^{85}Kr	^{232}Th
^{36}Cl	^{54}Mn	^{235}U

TABLE 3.1-1 Combined Radionuclide List		
^{58}Co	^{94}Nb	^{238}U
^{51}Cr	^{63}Ni	^{65}Zn
^{134}Cs	^{237}Np	^{95}Zr
^{137}Cs	^{238}Pu	

3.2 Screening of Radionuclides

For screening, CNS assumed a groundwater travel time of 20 years, reflecting the approximate groundwater travel between the closest trench to the creek. Most radionuclides migrate slower than groundwater due to adsorption by soils. For this evaluation, CNS has assessed radionuclides that have a travel time less than 2000 years. Two thousand years encompasses the 500-year compliance period and the 1000-years sensitivity period requested by SCDHEC. The 500-year compliance period is the time required for intruder protection from radioactivity indicated in SCDHEC Radioactive Material License 097, while the anticipated institutional control period for the disposal site is 100 years after the disposal site closes.

Certain radionuclides have short half-lives compared to their respective groundwater travel times. Radionuclides that have travel times greater than ten half-lives were eliminated. Radionuclides that have travel times greater than 2000 years were eliminated. The screening calculation has identified ^{3}H, ^{14}C, ^{36}Cl, ^{129}I, ^{237}Np, and ^{99}Tc as radionuclides that could reach the creek out of the list of radionuclides in Table 3.1-1.

Selected monitoring wells were sampled and analyzed specifically for ^{14}C, ^{36}Cl, ^{129}I, ^{237}Np, and ^{99}Tc in addition to the routine environmental monitoring measurements. Initial measurements for these specific radionuclides were made at monitoring locations selected for closeness to

disposal trenches, evidence of groundwater contamination and availability of water samples.

From routine environmental monitoring and ERPV radionuclide measurements, CNS has identified ^{3}H and ^{14}C as the only radionuclides measured outside disposal trenches and migrating in the groundwater due to the disposal of low-level radioactive waste. Based on this finding and routine measurements of elevated gross alpha and beta in trenches and groundwater, (Table 2.2-1) CNS has screened all ground and surface water monitoring points for elevated gross alpha and beta. Through this evaluation, CNS identified environmental monitoring points containing the highest gross alpha and beta measurements outside of trenches. Monitoring locations with the highest gross alpha or gross beta were analyzed for selected alpha or beta emitting radionuclides according to Table 3.2-1. These alpha and beta emitting radionuclides were chosen because they have been identified in liquid pathways at the Savannah River Site and are very restrictive according to SCDHEC.

Results of these measurements show the most likely source of gross alpha is ^{226}Ra. Radium-226 is naturally occurring radionuclide in the uranium series. The most likely source of gross beta is ^{14}C and ^{210}Pb. Lead-210 is a naturally occurring radionuclide in the uranium series decay chain. Other radionuclides that are part of the uranium and thorium series were detected at low concentrations in some water samples. All these radionuclides were determined to be naturally occurring by comparing results from groundwater containing tritium and groundwater that does not. This conclusion was based on showing that the presence of the naturally occurring uranium series radionuclides was not statistically different in samples containing tritium and those that did not. Therefore, CNS has identified ^{3}H and ^{14}C as the only two radionuclides migrating through the groundwater pathway due to the disposal of low-level radioactive waste.

TABLE 3.2-1	
Radionuclide	**Decay**
^{3}H	Beta
^{14}C	Beta
^{36}Cl	Beta
^{79}Se	Beta
^{99}Tc	Beta
^{129}I	Beta
^{210}Pb	Beta
^{241}Pu	Beta
^{90}Sr	Beta
^{237}Np	Alpha
$^{233}U/^{234}U$	Alpha
^{235}U	Alpha
^{238}U	Alpha
^{210}Po	Alpha
^{238}Pu	Alpha
$^{239}Pu/^{240}Pu$	Alpha
^{226}Ra	Alpha
^{228}Ra	Beta
^{241}Am	Alpha
^{228}Th	Alpha
^{230}Th	Alpha
^{232}Th	Alpha

3.3 Maximum Hypothetical Dose Rate at Chem-Nuclear Property Boundary

Chem-Nuclear conservatively estimates the maximum concentration of ^{3}H and ^{14}C using environmental monitoring data projected to the compliance point. Tritium data was obtained from over 200 monitoring locations over the time period of 1982 to 1998. Carbon-14 data was obtained from data collected during the ERPV in 1998. To determine maximum concentration at the compliance point, a model was used to project decay corrected measured groundwater concentration from the disposal site which flows in pathways to the creek (Figure 3-1). The highest average radionuclide concentration (C_{max}) found in Zone 2 groundwater monitoring wells (Figure 3-1), which intersect the flow paths, was used. The groundwater model

was used to determine travel time to decay tritium concentration during groundwater transport. (Carbon-14 was not decayed because it has a very long half-life relative to its travel time.) The groundwater model and stream flow measurements were used to determine volumetric flow rate of water containing decay corrected concentration, C_{max} that enters the creek. This determination projects highest averaged measured decay corrected groundwater concentration for all radionuclides at the creek, all arriving at the same time. Projected concentrations of radionuclides in the creek were diluted by waters containing background concentrations of radionuclides. The projected maximum concentration of radionuclides was calculated where the creek crosses the CNS property boundary or compliance point. Maximum concentration was converted to a hypothetical dose rate by using SCDHEC Regulation 61-63, Part III, Appendix B, Table 2, Column 2, effluent concentration. This table provides the concentration of specific radionuclides, which if ingested continuously (2 liters/day) over the course of a year will provide a total effective dose equivalent (TEDE) of 50 mrem.

Results of this analysis show the maximum projected hypothetical dose rate at the compliance point is 13 mrem per year TEDE with most of the dose from ^{3}H. Carbon-14 contributes much less than 1 mrem per year.

This approach is conservative because the calculation assumes (1) the arrival of maximum concentration of radioactivity in the creek occurs at the same time from all points on the disposal site; (2) maximum radionuclide concentrations near disposal trenches are constant, although recent measurements show decreasing concentration, (3) there is no consideration for effects of engineered covers which eliminates infiltration, and (4) once a groundwater pathway is contaminated, all waters in the pathway are assigned the same highest average concentration (C_{max} in Figure 3-1).

4.0 AIR

The purpose of the ERPV air pathway analysis is to determine if soil gas due to low-level radioactive waste might produce atmospheric air contamination approaching levels of regulatory concern. Much of these gases are believed to be generated as a result of physical decomposition of waste. Therefore, the planning and implementation of gas measurements are focused on sampling of the breathing zone when maximum soil gas concentrations are expected.

In the ERPV, CNS evaluated current radioactivity transport due to disposal of low-level waste by air pathways under natural conditions as follows. The source term is assumed to be gases generated as a result of the physical and chemical decomposition of waste disposed of at the Barnwell Site. For experimental design, CNS assumed that all trenches generate gases due to decomposition of waste, and the flux of gases are uniformly released to the land surface over a large area (Figure 4-1). For conservatism, the potential receptor was located on the disposal site and inhaled gas containing radioactivity.

Gas Sample - Experiment Design

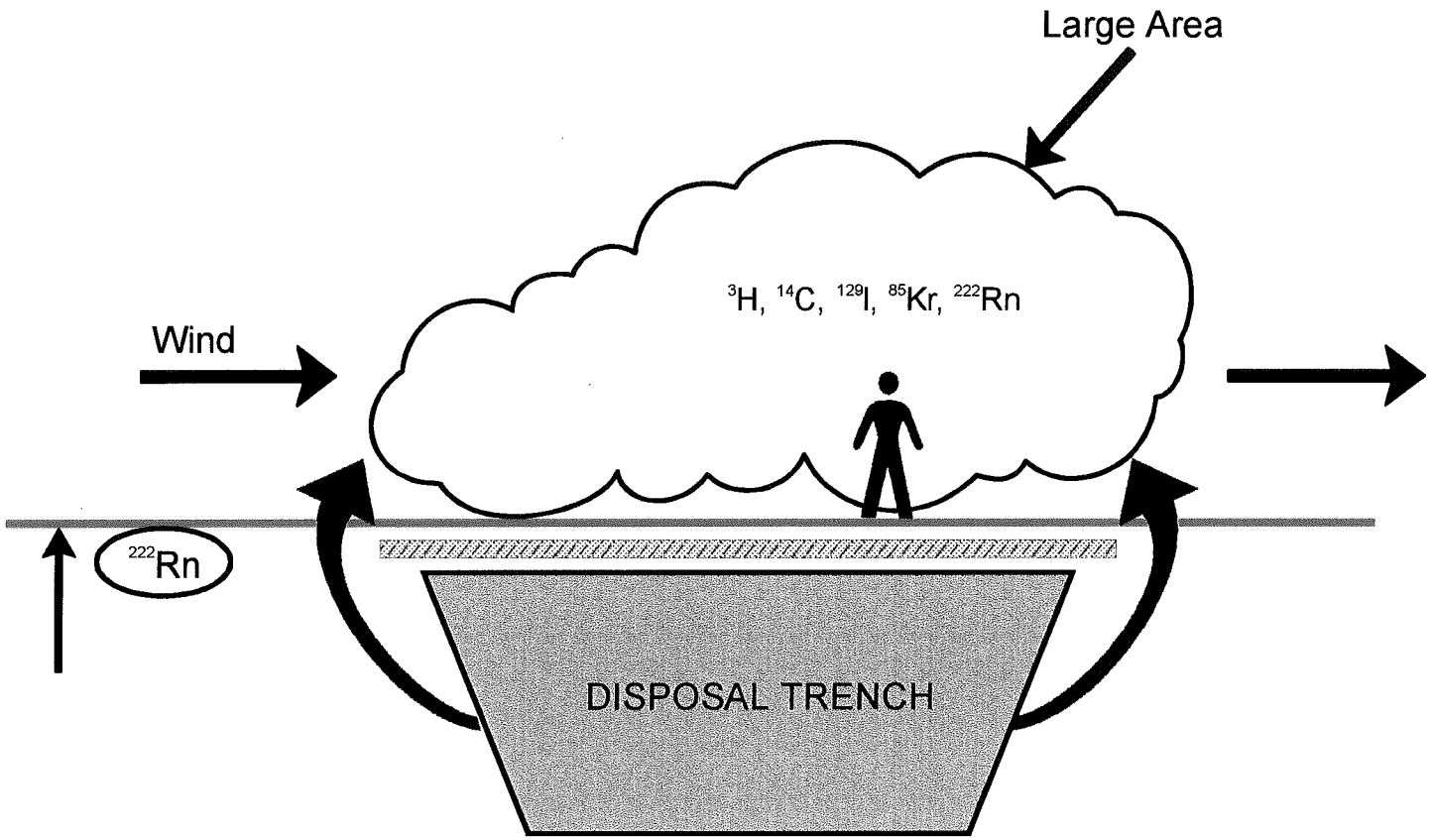

Figure 4-1: Gaseous Emission Model - Experimental Design.

4.1 Selection of Radionuclides

Prior to the ERPV, CNS had not collected and analyzed trench gases on the Barnwell Site. Therefore, the selection of types of radioactivity in gases was dependent on the literature data obtained from the West Valley, New York low-level waste disposal site. Radionuclides identified in gases in this study include ^{3}H, ^{14}C, and ^{85}Kr.

Iodine-129 was added because the NRC considers ^{129}I to be a potentially mobile radionuclide. For this study, CNS measures radionuclides ^{3}H, ^{14}C, ^{85}Kr and ^{129}I at breathing height on the land surface.

In addition to ^{3}H, ^{14}C, ^{85}Kr, and ^{129}I, CNS measured naturally-occurring ^{222}Rn gas in soil and in air. Radon gas at the land surface was assumed to be the result of decay of ^{226}Ra that is naturally occurring in near-surface soils. The amount of ^{222}Rn near the land surface due to low-level radioactive waste should be negligible because of the small quantity of radium in waste and the short half-life of ^{222}Rn. The diurnal maximum of ^{222}Rn concentration occurs at night and during the early morning hours when the atmosphere is stable. Therefore, CNS has sampled for ^{222}Rn at breathing level to determine when other gas samples should be taken at real-time. When ^{222}Rn in the atmosphere is highest, other soil gases in the atmosphere should be at maximum concentration.

4.2 Air Sampling

Chem-Nuclear attempted to measure the concentration of soil gases under conditions that should yield an upper estimate of radioactivity in gases within the breathing zone. Such conditions occur when the wind

velocity is negligible. These conditions which produce results that maximize air ^{222}Rn concentration typically occur on autumn mornings.

On-site air sample locations were located adjacent to the oldest trenches. Off-site air sample locations were chosen according to accessibility and located some distance from the burial site.

4.3 Results and Discussion

Chem-Nuclear used samples of soil gas at the land surface to determine if soil gas might produce atmospheric air contamination approaching levels of regulatory concern at the land surface breathing zone. The assessment was conducted on the disposal site because the air flow is omni-directional and a potential receptor could be located at numerous locations at the boundary of the disposal site.

Gas samples were collected during the fall of 1998 and 1999. Iodine-129, ^{3}H, and ^{14}C, and ^{85}Kr were not detected. Therefore, no dose to any member of the public adjacent to the disposal site is expected from radioactive gases.

Radon was easily measured in ambient gases at a maximum concentration of approximately 2 pCi/L during the soil gas sampling. Radon gas is the daughter of naturally-occurring radium in soils at the Barnwell site.

5.0 SUMMARY

5.1 Groundwater and Surface Water

CNS has shown that the maximum projected hypothetical dose rate is less than 13 mrem TEDE annually in surface waters leaving CNS property at the compliance point. Most of the hypothetical dose is due to ^{3}H. Actual dose from radionuclides leaving the CNS property boundary is negligible because there are no known consumers of surface water downgradient of the CNS property. Other potentially mobile radionuclides, such as ^{129}I, ^{99}Tc, ^{36}Cl, and ^{237}Np, have not been detected in the groundwater pathway.

5.2 Air

Carbon-14, ^{3}H, and ^{85}Kr were selected for air sampling based on measurements made at the West Valley, New York low-level radioactive waste disposal site. Iodine-129 was selected for air sampling based on NRC considerations. None of the four radionuclides were detected during the ERPV sampling. Therefore, based on measurements, no measurable dose to any member of the public adjacent to the disposal site is expected from radioactive gases.